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POLYMER ACTUATORS CONTRIBUTING TO ASTEROID MISSIONS

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The recent discoveries of polymers that induce large strain under electrical activation led to their consideration as potential actuators. The most attractive feature of Electroactive Polymers (EAP) is their ability to emulate biological muscles offering resilience, toughness, large actuation strain and inherent vibration damping. This characteristic similarity to biological muscles gained them the name "Artificial Muscles" and is offering the potential to develop biologically inspired robots. Such robots can be highly maneuverable, noiseless and agile, with various shapes allowing realization of science fiction ideas faster than ever been feasible. Unfortunately, their current actuation force and mechanical energy density are relatively low, limiting their potential applications. In recognition of the need for international cooperation among the developers, users and potential sponsors, the author organized though SPIE on March 1-2, 1999, the first EAP International Conference [Bar-Cohen, et al, 1999]. This Conference was the largest ever on this subject, making an important milestone and turning the spotlight onto these emerging materials. Following this success, an MRS Symposium was initiated to address the fundamental issues related to the material science of EAP. Further, the author established a homepage linking websites of worldwide EAP research and development facilities (http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-web.htm). He also initiated the electronic publication of the WW-EAP Newsletter and he helped establishing the WW-EAP Newsgroup.

In the coming years, the increased resources, growth in number of EAP researchers and improved collaboration among developers, users and sponsors are expected to accelerate the development progress. To promote the development of strong EAP and to highlight their potential, the author challenged the science and engineering community to develop a robotic hand actuated by EAP that would win an arm-wrestling match against human opponent. The progress towards this goal will lead to great benefits to mankind in medical, consumer products and many other areas (Figure 1).

FIGURE 1: Grand challenge for the EAP community.

Generally, operation in space is the most demanding conditions in terms of environment harshness and the requirements for robustness and durability with one-of-a-kind mechanisms. Taking advantage of the enormous potential of EAP for future planetary missions involves enormous challenges. Since 1995, the use of EAP for space applications has been the subject of research and development at JPL under the author's lead. The goal of his EAP project has been to improve the understanding, practicality

FIGURE 2: 4-finger EAP gripper lifting a rock much like a human hand.

and robustness of EAP while developing effective applications. Under this NASA funded project, longitudinal and bending EAP materials were used to produce a miniature robotic arm and a dust-wiper. The developed robotic arm allowed demonstrating the unique capabilities of EAP. An electrostatic EAP was used to lift and drop the arm where as a 4-finger Ion Exchange Metallic Composite (IPMC) gripper was used to grab various objects. As shown in Figure 2, when lifting the rock the fingers are operating much like a human hand. Even though this application has a relatively low technology readiness.

The applications of an EAP dust-wiper (Figure 3) received the most attention for its being considered by the MUSES-CN mission for the window of its Nanorover. MUSES-CN is a joint NASA and the NASDA (National Space Development Agency of Japan) mission scheduled for launch in January 2002, from Kagoshima, Japan, to explore the surface of a small near-Earth asteroid. As a bending actuator, IPMC was investigated jointly with NASA LaRC, USA, and Osaka National Research Institute and Kobe University from Japan. The team used perfluorocarboxylate-gold composite with two types of cations, tetra-n-butylammonium and lithium. The IPMC was used to bend a unique 104-mg blade having fiberglass brush (developed by ESLI, San Diego, CA). In addition to the mechanical brushing, the blade was subjected to high voltage (~1.5-KV) in order to repel dust. This effort to apply IPMC revealed three critical limitations that are hampering the launch of the EAP dust-wiper on the MUSES-CN mission. These limitations are (1) IPMC is sensitive to dehydration and the developed protective coating is ineffective; (2) Voltages above 1.03-V cause electrolysis releasing hydrogen and degrading the coating and the IPMC; and (3) IPMC suffers permanent deformation when activated by DC voltage. Overcoming these limitations is a challenge that is critical to the its future application.

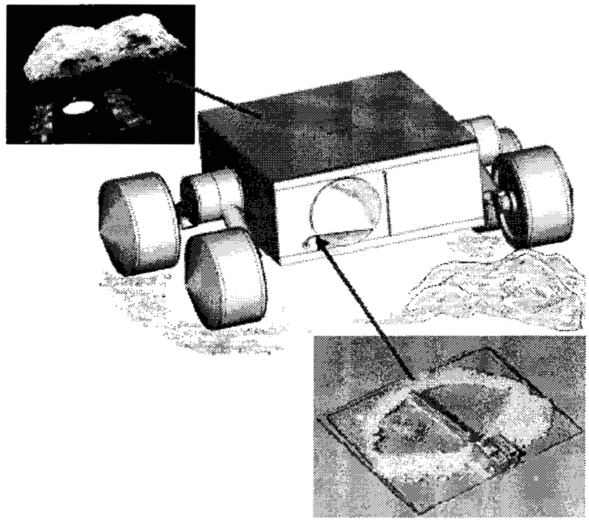

FIGURE 3: Schematic view of the EAP dust-wiper on the MUSES-CN's Nanorover (right) and a photograph of a prototype EAP dust-wiper (left).

In summary, EAP have emerged with great potential enabling unique mechanisms that can emulate biological systems. A series of materials were reported to induce large longitudinal and bending actuation. Effort to apply IPMC to a space application revealed limitations that cannot be addressed with current technology. Much more research and development work is ahead before EAP can become the actuators of choice. The potential to operate biologically inspired mechanisms driven by EAP as artificial muscles is offering capabilities that are currently considered as science fiction.

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REFERENCE

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